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WIREWORMS AFFECTING MAINE AGRICULTURE

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BULLETIN 343

WIREWORMS AFFECTING MAINE AGRICULTURE

(A Preliminary Report)[1]

J. H. Hawkins

Losses to Maine Agriculture Caused by Wireworms

Wireworms are well known pests of field crops and vegetable gardens. Depredations of these insects are not confined to Maine or the Eastern States, but are familiar to farmers and truck growers in practically every state in this country. In Maine, the central and southern farming sections have suffered heavily from injury inflicted to crops by wireworms. They have become so numerous and destructive that susceptible crops can not be grown profitably in certain low lying areas, and such crops may be affected during some years even on the higher and better drained soil of these sections. Only the potato growing region of Aroostook County seems not to have suffered greatly from the attack of these pests and offers interesting speculations as to why this is true. (See page 11).

The loss caused to Maine agriculture by wireworms is difficult of estimation, because of the variety of crops attacked and the number of ways in which injury may be done. Perhaps at no time in the history of the state have crops been entirely free from attack, although injury is greater some years than others. It may be safely estimated that thousands of dollars are lost annually by the farmers of the state through wireworm attacks. Sprouting seeds may be so injured by these destructive insects, that plants do not succeed in breaking through the ground. This type of injury involves either the extra expense of replanting, or loss due to a reduced yield because of a poor stand. Growing plants may be attacked and killed, or so badly injured that the growth is stunted and a full crop may not be harvested. If the plants survive, the mature crop may be attacked, as is the case with potatoes and

[1]Papers from the Maine Agricultural Experiment Station: Entomology No. 123.

other root crops. Often these crops are so badly damaged that a portion of the crop can not be marketed, thereby entailing the extra expense of sorting or grading. During years of severe infestation, wireworms may destroy entirely large portions of crops in certain fields. These barren spots, sometimes covering an acre or more, represent considerable loss in both time and money. Another prevalent way in which crops are injured often passes unnoticed or is attributed to other causes. This occurs when the wireworm attack is well distributed over the entire field in numbers sufficient to reduce the yield without killing many of the plants outright.

There is some danger of confusing the attack of wireworms with that of other insects. Since the injury is hidden beneath the soil surface, the only way to be sure of the identity of the pest is to dig up and examine injured or sickly plants. If wireworms are present, they may be found burrowing into the plants or living in the soil close by.

THE WHEAT WIREWORM, *Agriotes mancus* SAY

There are four stages in the life history of the wheat wireworm as described in the following pages. The wireworm or larva of this species is pale yellow in color and when fully grown is about three-fourths of an inch in length. It is well equipped for the subterranean life which it leads, with stout head and strong jaws or mandibles for pushing aside the earth and forming a passage-way through it. During molting, after the skin has been cast off and before the chitin has had time to harden, the larval body is soft and tender and very light in color. When first hatched, these larvae are also light in color and are very small. Various sizes ranging from very small ones to the full grown larvae may be found at any time, wherever they are numerous. Wireworms of this species are slender and cylindrical in form. The body is divided so that it has a ringed appearance. On each of the first three of these segments, just back of the head, is a pair of thoracic or true legs. A single leg-like structure known as the anal prop-leg is found on the lower side of the last body segment. This is the only support for the hinder part of the body. Long hairs invisible to the unaided eye are present on all segments of the body and may be seen with the aid of a hand lens. The head is armed with stout mandibles which serve as jaws and enable the insect to chew its way through plant tissues. The insect in this stage has

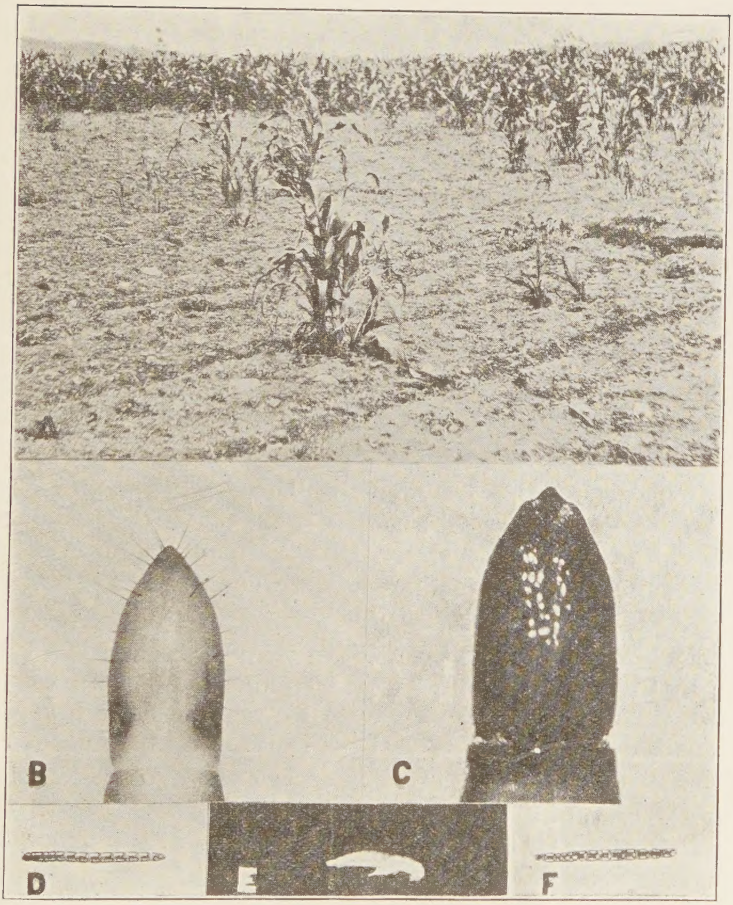

FIG. 1. A, Corn field devastated by wireworms; B, Anal segment of wheat wireworm; C, Anal segment of larva of Melanotus sp.; D, Wheat wireworm; E, Pupa of wheat wireworm; F, Larva of Melanotus sp.

no eyes, but the head is equipped with sensory appendages which enable it to find its way about beneath the surface and provide a means of detecting food. The wheat wireworm may be told from other Maine wireworms by the two dark eye-like spots on the dorsal side of the last or anal segment of the body. (Fig. 1, C).

The pupa of this species is white and rather slender. It resembles the adult in form somewhat, but is longer and has a more slender abdomen. The largest pupae of the wheat wireworm are little more than one-half inch in length and are poorly equipped to protect themselves. However, since they are hidden in the earth in the pupal cells during this stage, they are reasonably safe from enemies. (Fig. 1, E).

Adults of the wheat wireworm are small, stout, brown beetles scarcely three-eighths of an inch in length. Three main body divisions are recognized: head, thorax, and abdomen. The head bears the eyes and other sensory organs including the so-called feelers or antennae which are two in number. Closely joined to the head is the second body segment or thorax, bearing the three pairs of legs on the lower surface. Two pairs of wings, an outer pair of horny elytra and a thin filmy pair of inner ones are attached to the upper surface of this segment. The abdomen lies posterior to the thorax and is hinged to it, so that when placed on its back, the insect has the ability to snap its body so that it is thrown into the air. This habit has earned for it the common name of "skip jack or snapping beetle". When lately transformed from the pupa, this beetle is yellowish, but gradually changes to a dark chestnut brown which is retained throughout the rest of its life. (Fig. 2, I).

Eggs laid by this beetle seem not to have been described in papers published on this species. Attempts by the writer to secure eggs from beetles reared in cages and to find them in the field have not been successful. Judging from the eggs dissected from the body of a female, they must be very small. Their minuteness and the fact that they may be hidden in the soil or beneath rubbish, contribute to their obscurity.

Tiny eggs which are laid during late spring and early summer by the small chestnut colored adult "click beetles" or "skip jacks", hatch into small wireworms.[2] These larvae are pale yellow and are very small at first. They grow slowly during the remainder of the first season and go into hibernation at various distances be-

[2]See life history chart, Fig. 3, p. 7.

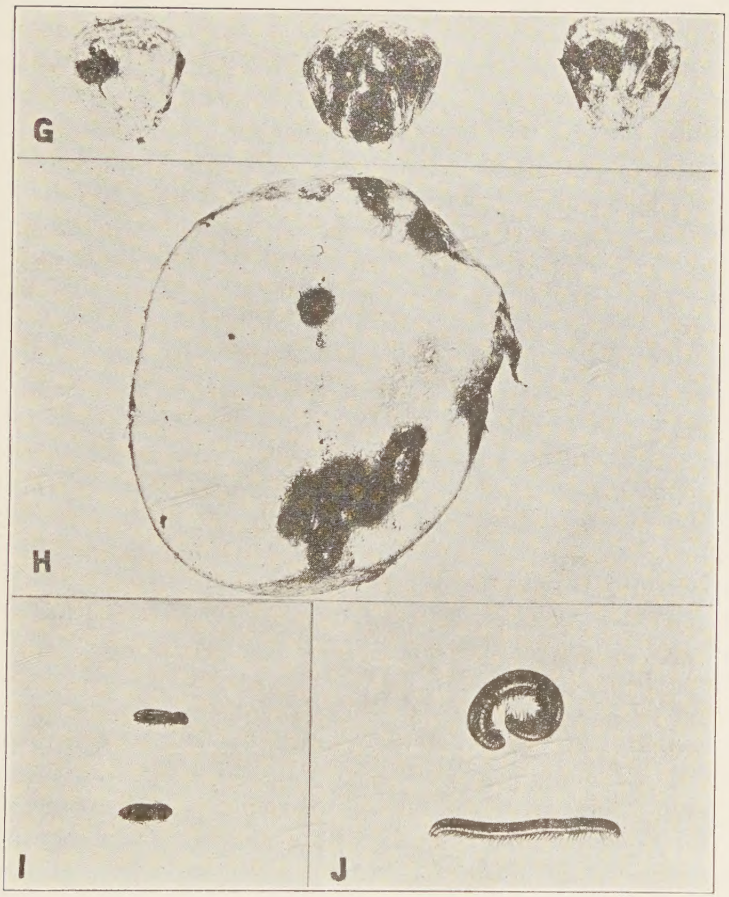

FIG. 2. G, Kernels of sweet corn showing wireworm injury; H, Potato burrowed by wireworms; I, Adult beetle of the wheat wireworm; J, Millepedes.

neath the surface of the soil, during the fall months of October and November. April and May find them working their way to near the surface where they begin feeding. It is during the second year that they have a long feeding and growing season. This period is, therefore, one during which much destruction is done. Again in the fall, they cease feeding and go deeper into the soil for winter hibernation. The spring of the third year finds the wireworm full grown, or nearly so. They work their way to near the surface at this time and begin to feed. The third season's injury is cut short, however, as the larvae start changing to pupae during late July or August. During the pupal stage the change from wireworm to beetle is accomplished. Pupation takes place in a cell in the soil from two to six or eight inches below the surface. This cell is made by the larva which twists about pressing the earth outward until an oval chamber large enough to accommodate the pupa has been made, after which the larval skin is pushed off and the pupa is formed. Two or three weeks are spent in the pupal stage in July or August. During this time the change from pupa to adult is accomplished. Pupae are incapable of any but very feeble movements. When first formed, the beetle is yellowish in color and the body is soft; but the chitinous body covering soon hardens and the color gradually becomes darker. When fully mature, our best known species are dark chestnut brown. They stay in the pupal cells during the first winter after they are formed, emerging the following spring as soon as the sun has warmed the soil a little. In April and May they begin to work their way to the surface and hide beneath stones, cavities in the soil, or bits of rubbish lying about on the ground. From these hiding places they come forth on warm days in June and run about on the surface seeking their mates. Afterward, dispersal of the females for egg laying or ovipositing begins. The favorite place for ovipositing by the female seems to be in meadows, weed grown areas, and grassy or weedy places that are undisturbed by cultivation. Of the eggs themselves, very little is known, except that they are very small and are thought to be laid during the summer and to hatch before fall.

AN UPLAND WIREWORM *(Melanotus sp.)*

While the wheat wireworm inhabits largely the moist spots in fields, another Maine species of wireworm belonging to the

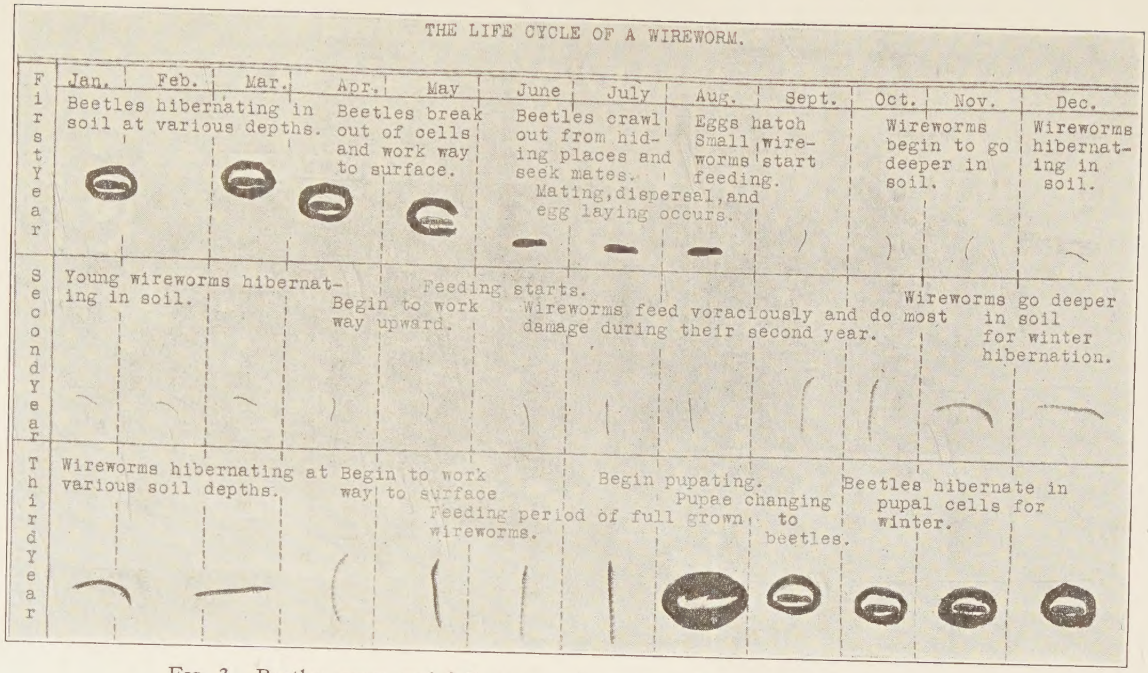

FIG. 3. Beetles, pupa, and full grown wireworms about two-thirds natural size.

genus *Melanotus*, lives in drier and better drained areas. It sometimes happens that both species are found in the same field and may even intermingle in the same habitat. Usually this species is not so destructive as the wheat wireworm as it has not the habit of concentrating its attack on a single plant until killed. The life cycle of this species seems to be longer than that of the wheat wireworm. This idea is borne out by one author who has described a member of this genus as having a 5-year life history (*4*)[3]. Often injury is well scattered over an entire field and only a few larvae attack any one plant. This wireworm attacks a wide range of crops including those attacked by the wheat wireworm. The former is more commonly a pest of gardens of the state than the latter. The larvae of this species of Melanotus when fully grown are larger than the wheat wireworm. They may be told from the wheat wireworm by the absence of the two eye-like spots on the dorsal surface of the anal or last segment, and the rather blunt termination of the body. (Fig. 1, B).

MILLEPEDES

An outbreak of so-called "black wireworms" was reported in the late summer of 1926. Upon investigation, the culprits were found to be millepedes. These creatures are not insects and they hatch from eggs laid by the female millepede, there being no adult stage comparable to the beetle of the wireworm. They injure sprouting seeds and growing plants in much the same way as wireworms, but are not regarded as being nearly so destructive. Very often wireworms and millepedes are associated together in the same fields, and are therefore sometimes confused. Millepedes which are usually found in the fields and gardens of Maine, are darker in color than the former, being black or quite dark brown. They may always be distinguished from them by their numerous legs, there being two pairs to each of the many segments of the body. (Fig. 2, J).

WIREWORM INJURY TO CROPS

Nearly all the common crops grown in Maine may be injured in a greater or lesser degree by the attack of wireworms. Because

[3]Reference is made by number (italic) to "Literature cited", p. 20.

of the extent of the territory over which corn and potatoes are grown, the large acreage, and the several ways in which these crops may be damaged, loss occasioned to them is probably greater than to any other single crop.

As soon as potato seed pieces are planted, these pests may start boring into them. This may induce rotting, prevent sprouting, or cause the production of weak plants. If vines are formed, the roots and underground portions of the stems may be attacked, thereby stunting the plant and resulting in weakened plants and a reduced yield of tubers. Sometimes the attack is delayed and the potatoes are injured after they have become well matured. At digging time the grower may then find that the tubers have been burrowed or their surfaces pitted by the feeding wireworms. (Fig. 2, H). These pests have become so abundant and destructive in certain fields that potato growing has been abandoned. There has been some question as to the possibility of a relationship between the Rhizoctonia disease of potatoes and injury done to the tubers by wireworms. A greenhouse experiment was carried on in conjunction with the Department of Plant Pathology of this Station to test the possibility of such a relationship. It was concluded from this experiment that wireworms facilitate the entrance by Rhizoctonia into the tubers. Larvae of the wheat wireworm, *Agriotes mancus,* were used in this experiment but both species described in this paper are known to attack potatoes.

Losses to the corn crop of the state due to wireworm attacks occur yearly, although as previously stated these attacks are much more severe some years than others. Seed corn is often injured soon after planting by burrowing wireworms which eat out the inside of the kernel often impairing germination. (Fig. 2, G). The rootlets of sprouting corn are sometimes attacked and serve as food for the pests until the larger roots are formed. As the plants gain in size, the roots and the underground part of the crown may be attacked, causing the stalks to fall or preventing the proper maturing of the crop. This type of injury is especially destructive to sweet corn, at times causing the formation of imperfect ears and a poor quality of corn for canning. Both canners and the growers suffer from such loss, as well as from low yields which result from injury of this kind. It is hard to estimate losses occasioned by light attacks of these subterranean insects; but the more severe attacks are very apparent and fields so attacked pre-

sent a sorry spectacle at the time of harvest. (Fig. 1, A).

Oat fields are sometimes injured by wireworms, but since there are a large number of plants present, the attack is not usually so serious as in the case of corn and potatoes where the number of plants is fewer per acre. Wheat is also subject to attack and is severely injured in other states. Nearly all the vegetable crops raised in gardens of the state may be damaged by wireworms. Cabbage, cauliflower, turnips, cucumbers, and beans are all recorded as hosts of these pests. It is a well known fact that wireworms live in meadows on the roots of grasses growing there. Witch grass is commonly attacked when growing in fields, and in one badly infested corn field dandelion and barnyard grass were found to be the host of wireworms.

WIREWORM CONTROL

Wireworm control has engaged the attention of economic entomologists for a long time. This problem has offered difficulties interesting and perplexing even to the most experienced workers, and while some effective control measures have been worked out, there seems to be no cheap and efficient means by which wireworms may be eliminated suddenly and permanently. Since wireworms have been with us a long time and are apt to remain for some time yet, it seems best to face the situation squarely and review such control measures as are known, keeping in mind especially those that may be adapted to local conditions. In the meanwhile some substances now being experimented with may prove practical for use in wireworm control.

Crop rotation. Wireworms breed most abundantly in soil which is not often disturbed by cultivation. In view of this fact it is inadvisable to permit land used in a corn or potato rotation to remain long in sod. Old meadows are often plowed up and planted to corn or potatoes, resulting in severe losses to these crops. The grower becoming discouraged, decides that it is best to keep such fields in meadows and sows them to grass again. If such fields had been continued in cultivated crops, it is most likely that little injury would have been experienced after the first few years, and that susceptible crops could then have been raised with profit. Experimental workers generally agree that crop rotation is one of the best control measures for wireworms. This may

explain why the Aroostook potato growers seem not to have been greatly troubled by wireworms, for as a rule they do not leave their land for a long period in meadows. This short rotation is unfavorable to breeding and accumulation of a large wireworm population, as it does not offer a period of years over which the adults may lay eggs.

Cultivated crops near infested areas may sometimes be attacked due to wireworm migrations. Investigations of gardens surrounded by meadows bear out this theory. It is also known that wireworms will move down a row of corn as the plants are destroyed. However, it is hardly likely that large fields would be seriously infested in this manner, especially if plenty of food were present in the original habitation. A study of wireworm structures reveals that, in the larval stage, they are poorly equipped for travel and while they can move swiftly for a short distance, they are rather awkward in their movements. They evidently migrate mostly beneath the soil's surface. If they are thrown out on the surface they at once endeavor to hide themselves in the soil again. These facts would indicate that wireworms do not ordinarily migrate from sod to cultivated fields, unless forced to do so by lack of food, and suggest the short rotation plan of cropping as a valuable control method. An ideal rotation would be one in which only cultivated crops were raised. Since this is sometimes impractical, however, some substitute for timothy in the rotation is advised.

Clean farming. Weedy areas make excellent breeding places for these insects. Such areas offer shelter and food for the adults and an opportunity to lay eggs unmolested. Conditions, too, are favorable to the newly hatched larvae. All weeds and grass around the edges of the fields should be cleaned up. Old stone walls grown up to brush and weeds are also objectionable features. Poorly cultivated fields in which weeds or witch grass are allowed to grow offer an opportunity for wireworm breeding. Cleaning up of crop remains such as injured potatoes, corn stalks, weeds, and cabbage leaves and stalks, is a good practice. In short, the less organic matter left in the soil upon which the wireworms might feed, the better. This is especially true if the control practice of baiting is to be resorted to.

Fall plowing. Since the wireworms begin to pupate in late July and August, plowing during August would be best. Pupae

and newly formed adults are most helpless at this time. This practice may also have some effect on the wireworms that are left in the soil, by killing some in the process of plowing and by exposing them to natural enemies. Fall plowing is not an effective wireworm control method when used alone. Moreover, in badly infested fields the wireworm population seems to have been little affected by fall plowing and pupae which have been taken from their earthen cells have continued to develop. However, the practice is valuable from a general agricultural standpoint and is a necessary first step in fallowing in case of old sod or after crops have been removed.

Fallowing. Preventing the growth of plants of any kind that serve as food for wireworms is a good control practice. This procedure has been recommended in the Prairie Provinces of Canada as a remedy against wireworms that attack wheat. The theory of this practice is that the wireworms are starved. Results of experiments tried elsewhere have not proven so favorable. If wireworms migrate at all, this practice would seem to drive them to seek food elsewhere, but until local experiments have been carried out proving this, it would hardly be advisable to lose the use of land for a whole year. It might be very much worth while to keep fallow, ground that had been plowed after the crop had been removed for the rest of the growing season on the assumption that the pupae and newly formed adults might be killed in some numbers. All stages would also be exposed to such natural enemies as might be present, as well as to adverse weather conditions. Fallowing is also a good practice for the control of objectionable weeds such as "kale" and "witch grass" and is a good farm practice in a general way. It is ordinarily necessary to successful baiting for wireworms. It seems likely that keeping of margins of fields fallow would serve as a protection, should wireworms for any reason start migrations into the field. On the other hand fallowing may result in destroying all vegetable matter in the soil upon which wireworms may feed. Then if crops are planted, the wireworms may be forced to start feeding at once on the newly planted seed and sprouting plants. On this account it has been suggested that the practice of plowing soil in spring after the grass has become green protects the young plants by placing the grass where it furnishes food for the pests. In an instance observed where this was done, it only resulted in delaying the attack as a large portion of the

crop was later destroyed. For this reason, it seems wise to practice cleaning up the wireworms by baiting or soil fumigation before planting the crop in fallow fields.

Immune crops. There seems to be some doubt as to whether or not there are any crops that are totally immune to the attack of wireworms, although there is no doubt whatever that some crops are preferred to others by these pests. Plants which have a seeming immunity, are in some cases immune from serious injury, only because of the large number of plants which grow within a given area. For instance, wireworms seldom become abundant enough in this state to ruin the grass stand in meadows, and rarely destroy a full stand of grain. Leguminous crops are not usually seriously injured and clover is recommended to take the place of timothy in the crop rotation of fields badly infested with wireworms. Canning peas, buckwheat, beans, and field peas are recommended as crops on infested land. Such crops are not usually severely injured but yellow eye beans were attacked and seriously damaged in at least one locality in the state during 1927. Millet and Hungarian planted as hay crops on soil that was so badly infested that sweet corn could not be raised, produced good returns in central Maine during 1927. These plants are early maturing and offer an opportunity for early fall plowing and fallowing. It is recommended that land badly infested with wireworms first be planted with some crop not subject to serious injury following sod of long standing. After such crops are grown for three years, then corn and potatoes may be planted on infested soil with comparative safety.

Fertilization. A high yield of sweet corn was produced by a central Maine grower in a field heavily infested with wireworms, during the season of 1927. This was accomplished by the judicious use of a combination of barnyard manure and commercial fertilizer. The crop was really forced to grow and mature in spite of the attack. Perhaps the success of the crop was partly due to the fact that a large per cent of the wireworms present belonged to a species of *Melanotus* which has the habit of disturbing their attack, so that a great many larvae are not usually found near a single plant, but a large number of plants are attacked. However, this does not detract from the value of fertilizer as a means of giving plants strength to withstand the ravages of these destructive insects. Fertilizers as a rule have no value either as a repellent

or as an insecticide, as far as wireworms are concerned, and the numbers in a treated field will not be diminished by their use.

Drainage. Drainage has been recommended as a control measure for wireworms by certain investigators of the subject. That this may have some effect in reducing the number of wheat wireworms, is a conclusion arrived at after observations made on a central Maine farm. On one side of the road a field which is not tiled and which has poor natural drainage, is badly infested in the low spots by wheat wireworms. On the opposite side of the road another field which is tiled and has fairly good natural drainage is free from severe infestation, although there may be other contributing factors. If all the fields now infested by this species were well drained, the numbers would undoubtedly be decreased. Unfortunately drainage is not always practical by use of tile, but a system of open ditches which would carry off the water immediately would make conditions less habitable for the wheat wireworm. It would probably not affect the Maine species of *Melanotus,* as they seem to thrive in higher and better drained soil than the former. It appears that soil texture and materials play some part in determining the habitat of wireworms, but that food, moisture, and a suitable place for breeding are perhaps more important factors.

Repellents and seed treatments. Paradichlorobenzene was tried out in two Maine localities during the spring of 1927. Amounts varying from 100 pounds to 200 pounds per acre were used. There seemed to be no effect on the number of wireworms in the treated plots. However, the soil was wet in one of these places at the time of application. At the present prices this substance would not be practical under Maine conditions in greater amounts than 100 to 150 pounds per acre, even if it should prove effective. Sooner or later, practically every one hears of something which is a sure cure for wireworms. Substances which may be used to coat seeds and act as a repellent have been often recommended. Nearly every substance that could have a practical value for this purpose has been tried (2, p. 200). As far as can be learned, not a single one of these has had the desired effect.

Parasitic and predaceous insects: fungi. In view of the fact that so much has been accomplished in control of certain insects by use of parasites, it might seem feasible to suggest their use as a means of combating wireworms. Since wireworms are subter-

ranean in habit and are well protected by hard armor-like body covering, they are difficult prey for parasites or predators, although the larva of a common ground beetle has been observed eating a wireworm. Forbes reports a parasitic fly as attacking what he judged to be the larva of *Melanotus fissilis* in Illinois (3, p. 41), but the whole history of wireworm depredations gives no reason to expect immediate relief by parasite control. As a whole, wireworms were not as plentiful during the season 1927 as they were in 1926. This is especially true of the destructive wheat wireworm. In areas in which the vegetation was entirely destroyed in 1926, wireworms appeared abundantly during the warm spell in April, and were fairly abundant during the early part of May. A rainy, cold spell set in and continued intermittently well into June after which, very few wireworms were found in several such areas visited. On the other hand many more of the native species of *Melanotus* were found during 1927, than during 1926. These facts would indicate, that for some reason the wheat wireworms living in wet places were killed, while wireworms living on higher ground apparently thrived. Conditions in the wet places seemed to be unfavorable for parasitic attack and no parasites were reared from wireworms taken there. In cage experiments in New York, Comstock and Slingerland record a fungous disease as attacking wireworms in their breeding cages (2, p. 228). Conditions were favorable for the growth of the fungus and may partially account for the above disappearance. Certain seasons are more favorable to fungous growth than others and may account for years of relative scarcity. These points can be cleared up only by a study of conditions extending over a period of years, and until then we can not be certain of the reasons for sudden variations in wireworm numbers from one year to another.

Birds. The part played by birds in the control of insects is important. If we may judge from records obtained elsewhere, wireworms serve as food for several species of birds. The common robin, the brown thrush, the hermit thrush, the wood thrush, and the Alice thrush are reported as feeding upon either the "click beetles" or the larvae (3, p. 41). Crows are also said to feed upon wireworms. It has been observed that crows feeding in corn fields appear to prefer those areas which were infested by wireworms. This may indicate that they were feeding upon these larvae as well as the sprouting corn; but be that as it may,

wireworms and their adults are said by one investigator to constitute the favorite food of crows (3, p. 42). While birds do much good in controlling insects in general and may be valuable in wireworm control, it is not likely that they will become numerous enough to clean up severe infestations of these pests.

Calcium cyanide. When used as a soil fumigant, this substance gives off a powerful gas which will kill wireworms. It is a deadly poison. It kills all living things in the soil if applied in sufficient amounts. For this reason, it can not be safely used in heavy dosages near growing plants. Ordinarily the spring is the best time to apply calcium cyanide to the soil, for then the temperature is rising, the soil is moist, and the wireworms are active. If the springs are wet and cold, this substance will not be so effective, as the gas can not readily permeate wet soil and the wireworms seem harder to kill when inactive. The use of calcium cyanide depends for its success upon several factors which should be carefully considered before applying (1, p. 563). The soil should be first of all, fairly dry, but with enough moisture to evolve the gas. The temperature should be high enough to enable free movement of the insects in the soil, as well as facilitating the evolution of the gas. The soil should be in good mechanical condition so that it will not permit the gas to be dispersed into the air too quickly and yet not so hard packed or finely pulverized as to prevent the free passage of the gas beneath the soil's surface. Weather conditions in Maine are sometimes unfavorable in spring for the application of calcium cyanide but if conditions are watched carefully, there is usually a favorable opportunity some time before planting that may be used for applying the fumigant. Experimentation carried out elsewhere and verified under Maine conditions indicates that to be most effective, the poison should be applied at the same depth as the greatest wireworm concentration (1, p. 563). The gas seems to move upward and outward rather than downward. Fumes from this substance are deadly and it should be carefully handled so as to avoid breathing the gas. After the soil has been treated, a week or ten days should elapse before crops are planted to insure the safety of sprouting seed (1, p. 566).

There are several ways of applying calcium cyanide to the soil. It may be broadcast and then worked in by harrowing or cultivating, it may be drilled by the use of a drill, or it may be

placed on the surface with a lime applicator and plowed under (5, p. 183). The method of broadcasting has the advantage that the soil may be put in good mechanical condition before the material is covered; but some of the effect of the gas may be lost due to insufficient covering. Applying just ahead of the plow provides for the covering of the substance at once, thus preventing the escape of much of the gas to the air, and if the soil is worked down soon afterward into good mechanical condition, it should prove a very good method of application. Drilling is a method that could undoubtedly be used to an advantage. Drills six or eight inches apart, and placed at the proper depth, should thoroughly fumigate the soil (1, p. 565). This method also has the advantage of applying the cyanide after the ground has been put in good mechanical condition and in addition the substance is in rows close enough together to be effective. The use of a drill in applying calcium cyanide makes possible the treatment of large areas economically and does away with hand labor entirely, in the actual application. Regulation of the amount to be applied is important and this may be done with certain types of drills. About 300 pounds of calcium cyanide are needed per acre to effect commercial control in infested areas (6, p. 704). This costs approximately $25 per hundred and at this rate it is too expensive for general use. The fact that the effects will last for three years should be taken into consideration, however, and where small areas are to be treated or valuable crops are to be raised, its use as above would probably be warranted.

Baiting. Experiments have been tried on methods by which the amount of calcium cyanide required per acre may be reduced. The concentration of wireworms into small areas by the use of baits and subsequent treatment with calcium cyanide has been a more or less successful method arrived at (6, p. 707). Baiting is effective only in soil that is free from organic matter upon which the wireworms will feed, or by use of baits that are more attractive to wireworms than the natural food present. It seems much safer to have the soil fallow than to risk finding a bait attractive enough to draw them from food already in the soil. This is especially true if they are feeding upon growing plants. For the same reason, it is better to place baits in the soil before planting crops than to chance their preference for the baits afterward. Of baits tried by the writer, wheat has proven most effective both under

spring and summer conditions. Corn and graham flour are fairly satisfactory but are not so attractive to wireworms as sprouting wheat. Wheat offers the advantage that it may be sown with a drill, thereby saving hand labor. Corn can also be drilled. Graham flour which must be made into balls and placed in the soil by hand also entails the extra labor of hand fumigation while with corn or wheat the same drills may be used for the distribution of the poison as for the sowing of the grain. Wheat, corn or graham flour dough may be placed by hand. The method followed in experiments carried out by the writer during the summer of 1926 was as follows: Corn, wheat, oats, graham flour, and potatoes were placed in rows three feet six inches apart and three feet distant in the rows. The baits were about four inches deep in the ground. They were left undisturbed for about ten days and then each bait received about one-fourth ounce of granular calcium cyanide. Again they were left for ten days to give the gas time to work thoroughly through the soil. Examinations were then made. It was found that from 75 to 96 per cent of the wireworms had been killed in case of the wheat and corn baits. The results obtained from potatoes were practically negligible, while those from oats were somewhat lower than any of the other baits used except potatoes. Wheat was by far the most attractive bait used, averaging 15 wireworms per bait. Wheat used in the spring of 1927 also proved attractive, but the average number attracted was much lower, due to wet, cold weather continuing well into the summer. This method has the distinct advantage that only about one-half as much calcium cyanide is needed per acre as in the case where the material is broadcast or drilled over the entire field. Probably rows two feet apart would be more effective than those as used in the above experiment.

Trapping adults. If all the beetles could be trapped and killed, there would be no more eggs laid and consequently no more wireworms. It was discovered that beetles will come to baits of chopped clover and to poisoned sweetened corn meal dough (2, p. 248). It seems worth while to try trapping adults with chopped clover dipped in Paris green water. This will probably be only partially effective, for there are many places in this state where wireworms breed in which trapping would not be feasible. If concerted movements were made and the beetles trapped and killed, much good would be accomplished. Two serious difficulties lie

in the way of doing this: first it is almost impossible to carry out such a plan because of the large acreage of meadows in the state; secondly, it is difficult to find a bait that is always attractive and to so place it that it will be effective. Methods of trapping adults have not been worked out thoroughly, but in view of the small expense involved it seems worth while to try this measure especially in fields where wireworms have been abundant the previous season. Such baits are said to be most effective when placed under boards or rubbish to prevent drying out.

Recommendations

General farm practices such as crop rotation, clean farming, fallowing, immune crops or resistant crops, judicious use of fertilizer, are all methods that may be safely adopted as aids in the control of wireworms. These practices are good from the standpoint of good farming besides their value as control measures. The practicability of the methods to be employed must be considered in individual cases, and that method or combination of methods best fitted to local conditions be adopted by the grower. It is well to keep in mind that any preventive measure is worth more than a cure. An examination of the soil should be made during the fall and again in the spring before planting time. A few trial baits of a handful of wheat or corn would be likely to attract any wireworms that may be living in suspected places.

The results of experimentation in Maine agree with the general conclusion that calcium cyanide is an effective soil fumigant for wireworms. It seems impractical to use any method of application by which the whole infested area is treated unless a valuable planting is involved. In order to make practical the use of calcium cyanide, baiting may be resorted to. In this way, the cost of the material is reduced by about one-half. Baiting is said to be most effective in spring, but weather conditions in Maine have not been favorable lately to spring baiting. Fall and summer baiting with wheat in infested corn fields and subsequent fumigation with cyanide has proven effective. The subject of spring baiting for wireworms needs further investigation before sweeping recommendations are made to Maine growers.

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